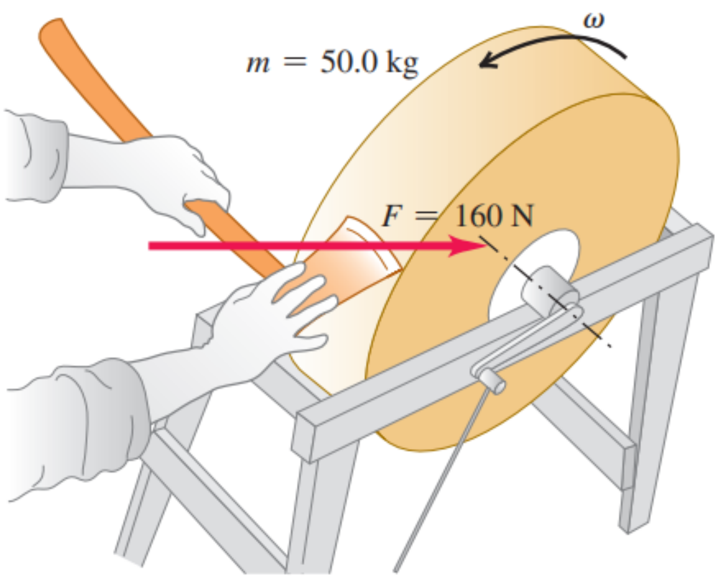
Question 1:

B



A $50.0\ \mathrm{kg}$ grindstone is a solid disk $0.520\ \mathrm{m}$ in diameter. You press an ax down on the rim with a normal force of $160\ \mathrm{N}$ as shown in figure. The coefficient of kinetic friction between the blade and the stone is 0.60, and there is a constant friction torque of $6.50\ \mathrm{N} \cdot \mathrm{m}$ between the axle of the stone and its bearings. How much time does it take the grindstone to come from $120\ \mathrm{rev/min}$ to rest if it is acted on by the axle friction alone?

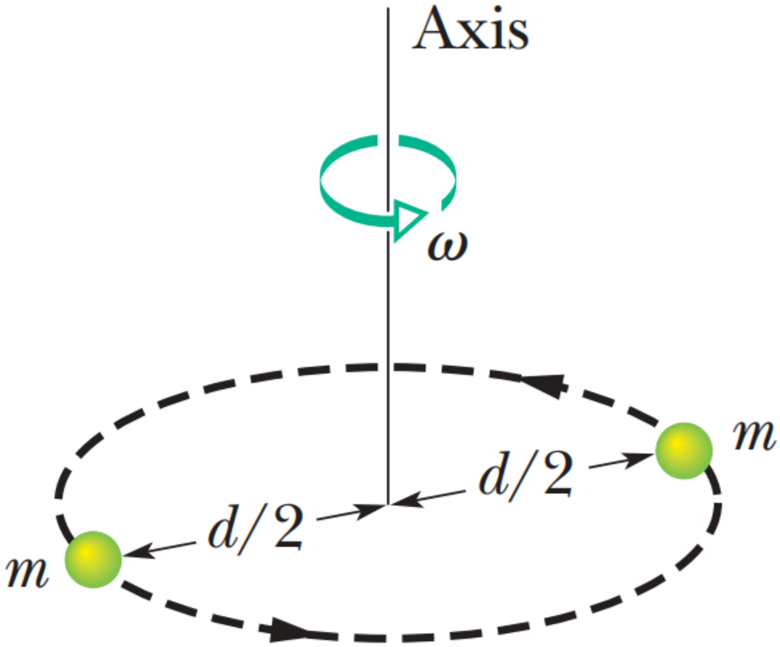
A. 4.86s

B. 3.27s

C. 5.23s

D. 6.86s

Question 2:



A diatomic gas molecule consists of two atoms of mass m separated by a fixed distance d rotating about an axis as indicated in figure. Assuming that its angular momentum is quantized as in the Bohr model for the hydrogen atom, find the possible quantized rotational energies.

$L = n\hbar$.

$I\omega = n\hbar$

$\omega = \frac{n\hbar}{I}$.

$E = \frac{1}{2} I \omega^2 = \frac{n^2\hbar^2}{2I}$.

Substituting $I = \frac{md^2}{2}$.

$E = \frac{n^2\hbar^2}{md^2}$. where $n = 0, 1, 2, 3$.

Question 3:

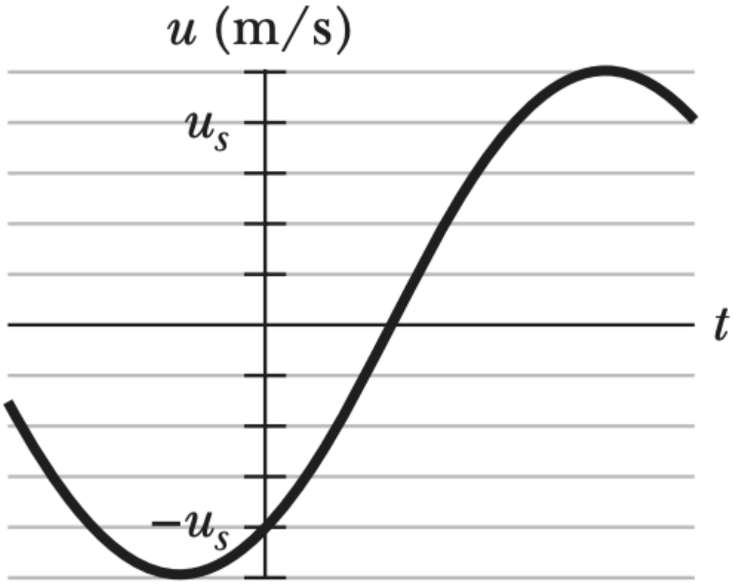


Figure shows the transverse velocity u versus time t of the point on a string at $x = 0$, as a wave passes through it. The scale on the vertical axis is set by $u_s = 4.0$ m/s. The wave has the generic form $y(x,t) = y_m \sin(kx - \omega t + \phi)$. What then is ϕ?

For a wave at $x=0$, the transverse velocity is:

$u = \frac{\partial y}{\partial t} = -y_m w \cos(kx - wt + \varphi)\Big|_{x=0} = -y_m w \cos(-wt+\varphi)$

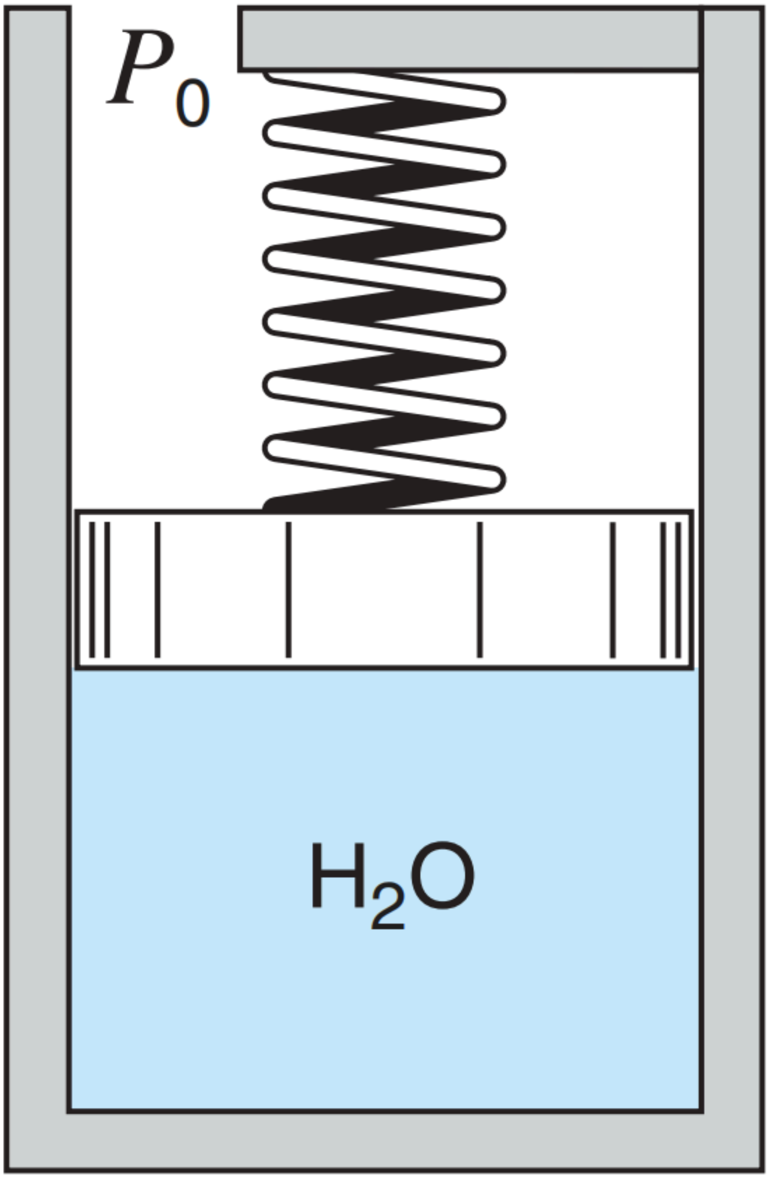
from the graph at $t=0$ $u = -u_s = -4.0$ m/s

$\therefore -y_m w \cos\varphi = -4.0$.

For the velocity to be maximum negative $\cos\varphi$ must be 1

$\therefore \varphi = 0$

Question 4:

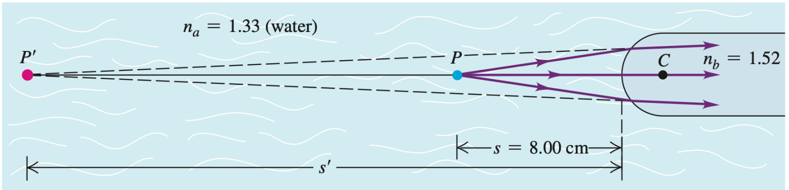


A piston/cylinder assembly contains $2\,\mathrm{kg}$ of liquid water at $20\,^{\circ}\mathrm{C}$ and $300\,\mathrm{kPa}$, as shown in figure. There is a linear spring mounted on the piston such that when the water is heated, the pressure reaches $3\,\mathrm{MPa}$ with a volume of $0.1\,\mathrm{m}^3$. Find the work in the process.

$V_1 = m/\rho = \frac{2kg}{998kg/m^3} = 0.002m^3$

work $= \int P \cdot dV$ from V_1 to V_2.

Question 5:



A cylindrical glass rod (figure) has index of refraction 1.52. It is surrounded by water that has index of refraction of 1.33. One end is ground to a hemispherical surface with radius $R = 2.00\ \mathrm{cm}$. A small object is placed on the axis of the rod, 8.00 \ \mathrm{cm} to the left of the vertex. Find the lateral magnification.

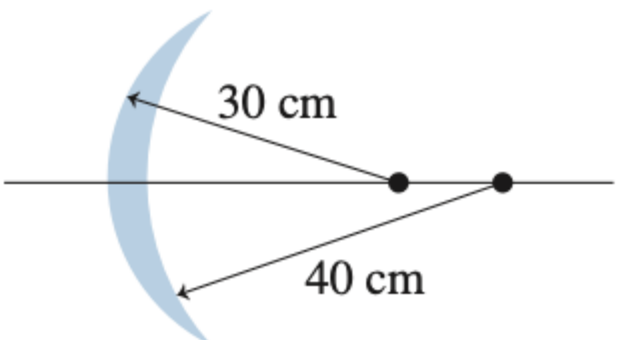
For a convex surface from water to glass with $s = 8.00$ cm $R = 2.00$ cm

$$\frac{1}{s'} = \frac{1.52-1.33}{1.33\times 2} - \frac{1}{8} = 0.0536$$

$$s' = -18.66\text{cm}.$$

$$M = \frac{s'}{s} = \frac{-(-18.66)}{8.00} = 2.33$$

Question 6:



Meniscus lens

Find the focal length of the meniscus polystyrene plastic lens Find the focal length of the meniscus polystyrene plastic lens

$$\because \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\therefore \frac{1}{f} = (1.59-1)\left(\left(\frac{1}{30}\right) - \left(\frac{1}{-40}\right)\right) = 0.0344$$

$$\therefore f = \frac{1}{0.0344} = 29.1\text{cm}$$

Question 7:

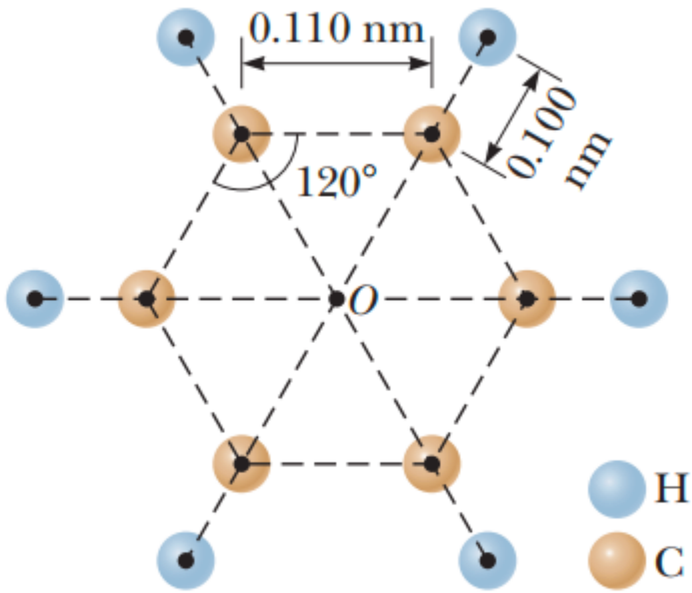


Figure is a model of a benzene molecule. All atoms lie in a plane, and the carbon atoms ($m_{\mathrm{C}} = 1.99 \times 10^{-26}$ kg) form a regular hexagon, as do the hydrogen atoms ($m_{\mathrm{H}} = 1.67 \times 10^{-27}$ kg). The carbon atoms are 0.110 nm apart center to center, and the adjacent carbon and hydrogen atoms are 0.100 nm apart center to center. Calculate the moment of inertia of the molecule about an axis perpendicular to the plane of the paper through the center point O.

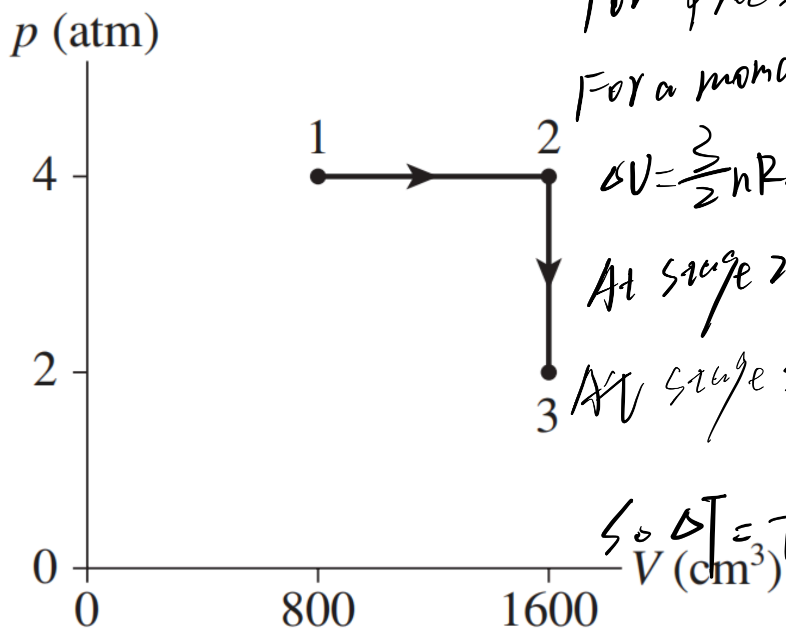
A. $2.31 \times 10^{-45}\ \mathrm{kg \cdot m^2}$

B. $1.65 \times 10^{-45}\ \mathrm{kg \cdot m^2}$

C. $1.05 \times 10^{-45}\ \mathrm{kg \cdot m^2}$

D. $1.89 \times 10^{-45}\ \mathrm{kg \cdot m^2}$

Question 8:



For process $2 \to 3$, $Q = \Delta U + W$.

Change V

For a monatomic gas, the internal energy is

$\Delta U = \frac{3}{2} nR\Delta T$.

At stage 2: $T_2 = \frac{P_2 V}{nR} = \frac{4atm \times 1600cm^3}{0.10mol \times R}$

At stage 3: $T_3 = \frac{P_3 V}{nR} = \frac{2atm \times 1600cm^3}{0.10mol \times R}$.

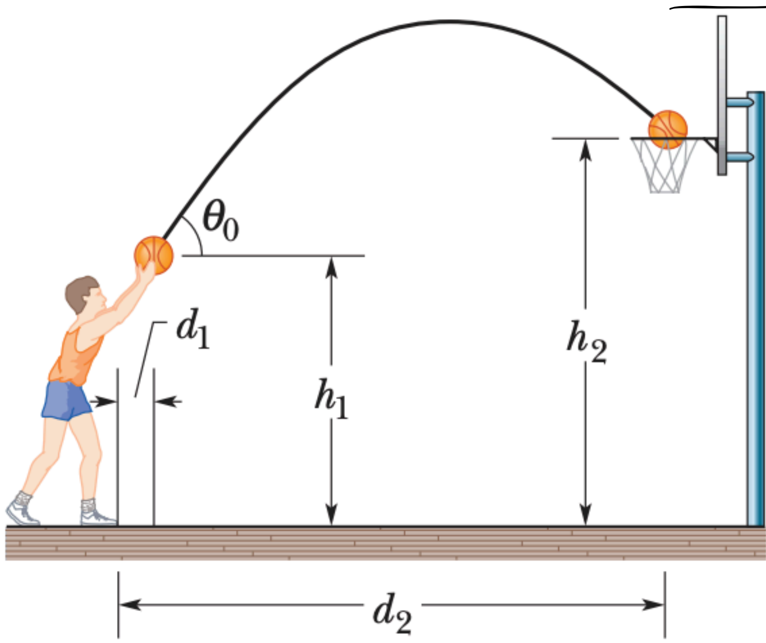
So $\Delta T = T_3 - T_2 = \frac{V(P_3 - P_2)}{nR} = \frac{1600cm^3(-2atm)}{0.10mol \times R}$.

0.10 mol of a monatomic gas follow the process shown in figure. How much heat energy is transferred to or from the gas during process $2 \rightarrow 3$?

$\Delta U = \frac{3}{2} nR\Delta T = \frac{3}{2} nR \times \frac{V(P_3 - P_2)}{nR} = \frac{3}{2} V(P_3 - P_2)$

$\Delta U = -486J$.

Question 9:



$V_x = V_0 \cos 55°$ $V_y = V_0 \sin 55°$

$t = \frac{d_1 + d_2}{V_x} = \frac{15ft}{V_0 \cos 55°}$.

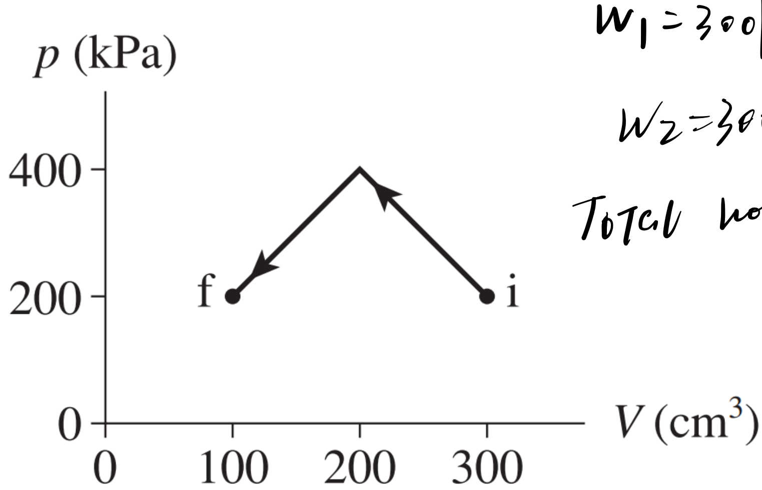
Final height $h_2 = h_1 + V_y t - \frac{1}{2} g t^2$

$10ft = 7ft + V_0 \sin 55° \times \frac{15ft}{V_0 \cos 55°} - \frac{1}{2} 32.2ft/s^2 \times \left(\frac{15ft}{V_0 \cos 55°}\right)^2$

The horizontal distances are $d_1 = 1.0\ ft$ and $d_2 = 14\ ft$, and the heights are $h_1 = 7.0\ ft$ and $h_2 = 10\ ft$. At what initial speed must the basketball player in figure throw the ball, at angle $\theta_0 = 55°$ above the horizontal, to make the foul shot?

$V_0 = 22.9\ ft/s$

Question 10:



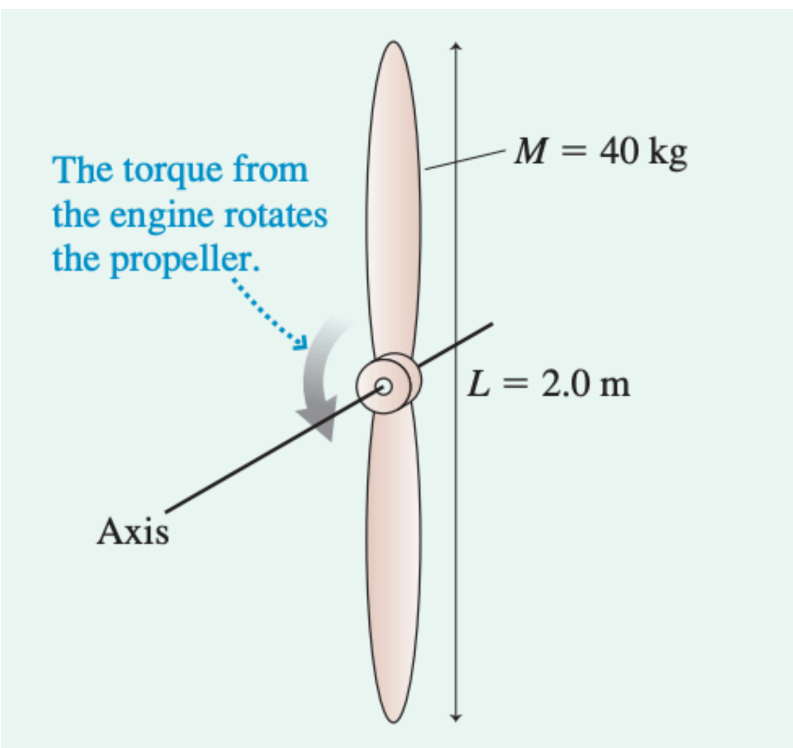
$W_1 = 300kPa \times 100cm^3 = -30000 Pa \cdot cm^3 = -3J$

$W_2 = 300kPa \times (-100cm^3) = -3J$.

Total work $W = W_1 + W_2 = -6J$

A gas is compressed in two stages. First, its volume decreases while pressure rises. Then, its volume further decreases as pressure declines, resulting in a smaller final volume. How much work is done on the gas in the process shown in figure?

Question 11:



$\alpha = \tau / I$

$I = \frac{1}{12} ML^2$.

$I = \frac{1}{12} 40kg \times 2m^3 = 13.33 kg \cdot m^2$

$T = 60N \cdot m$.

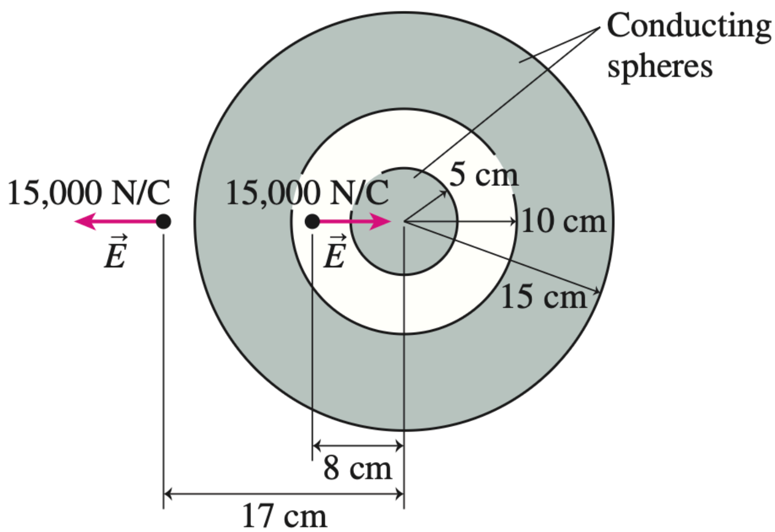
$\alpha = \frac{60}{13.33} = 4.5 rad/s^2$

Final angular velocity $w = 200rpm = 200 \times \frac{2\pi}{60} = 20.94 rad/s$

$t = \frac{w}{\alpha} = \frac{20.94}{4.5} = 4.65s$.

The engine in a small airplane is specified to have a torque of $60\,\mathrm{N\,m}$. This engine drives a $2.0\,\mathrm{m}$-long, $40\,\mathrm{kg}$ propeller. On start-up,how long does it take the propeller to reach $200\,\mathrm{rpm}$?

Question 12:

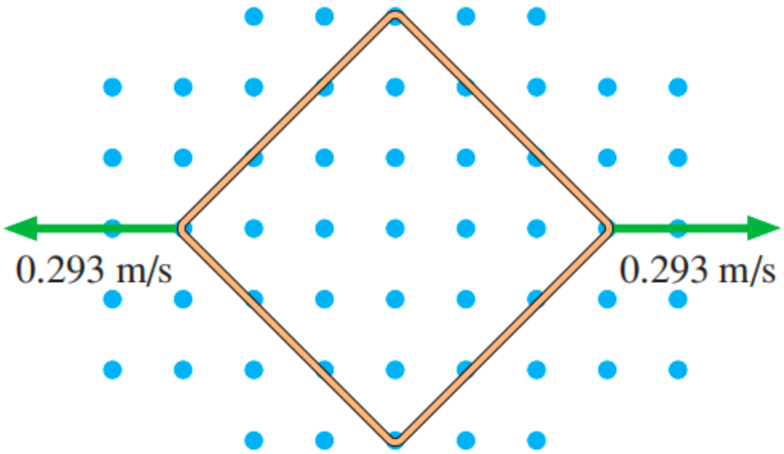


The figure shows a solid metal sphere at the center of a hollow metal sphere. What is the total charge on the inside surface of the hollow sphere?

From the figure, the electric field strength at 17cm is 15000 N/C.
The electric field from a point charge is $E = \frac{kQ}{r^2}$, so we can determine the charge on the central sphere and thus the charge on the inner surface of the hollow sphere

Since the charge on the inner surface of the hollow sphere must be equal and opposite to the charge on the solid sphere, so the answer is negative of the central sphere's charge.

Question 13:



A closed, square loop is formed with 40 cm of wire having $R = 0.10\,\Omega$, as shown in figure. A 0.50 T magnetic field is perpendicular to the loop. At $t = 0\,\mathrm{s}$, two diagonally opposite corners of the loop begin to move apart at 0.293 m/s. How long does it take the loop to collapse to a straight line?

A. $0.7\,\mathrm{s}$

B. $0.3\,\mathrm{s}$

C. $0.1\,\mathrm{s}$

D. $0.9\,\mathrm{s}$

Question 14:

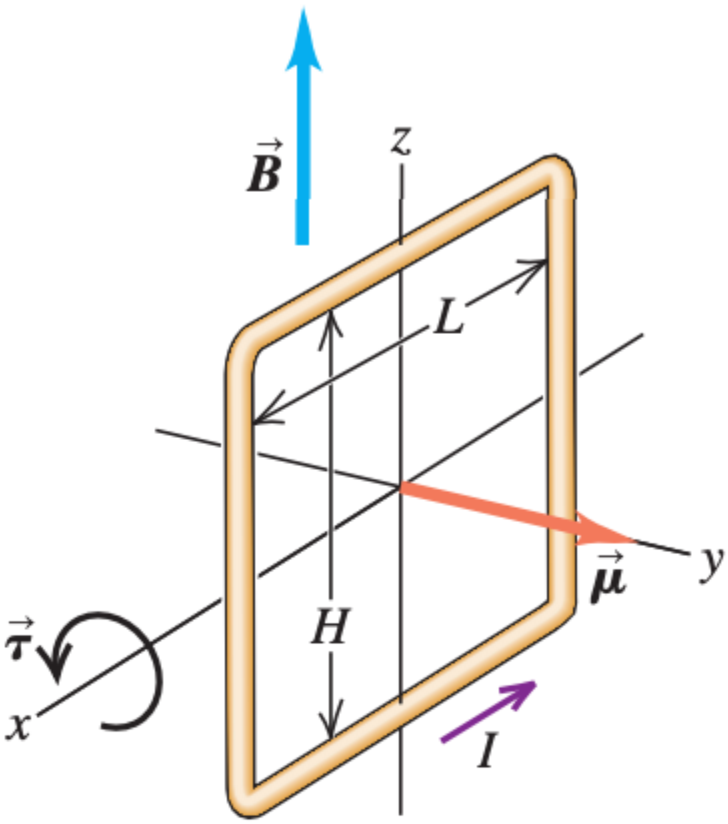
A steel wire is used to stretch the spring of figure. An oscillating magnetic field drives the steel wire back and forth. A standing wave with three antinodes is created when the spring is stretched $8.0\,\mathrm{cm}$. What stretch of the spring produces a standing wave with two antinodes?

$V_1^2/V_2^2 = \frac{T_1}{T_2} = \frac{x_1}{x_2}$. $L_1 = \frac{3\lambda_1}{2}$ and $L_2 = \lambda_2$. $(L_1/L_2)^2 \times \left(\frac{1}{\frac{2}{3}}\right)^2 = \frac{x_1}{x_2}$.

Sin $\lambda = V/f$ $\quad \frac{\left(\frac{L_1}{\frac{3}{2}}\right)^2}{\left(\frac{L_1}{1}\right)^2} = \frac{x_1}{x_2}$. $\quad \therefore x_2 = x_1 \times \left(\frac{L_2}{L_1}\right)^2 \times \left(\frac{3}{2}\right)^2$

$\lambda_1^2/\lambda_2^2 = \frac{V_1^2}{V_2^2} = \frac{x_1}{x_2}$, $\quad x_2 = 8.0\,\mathrm{cm}$.

Question 15:



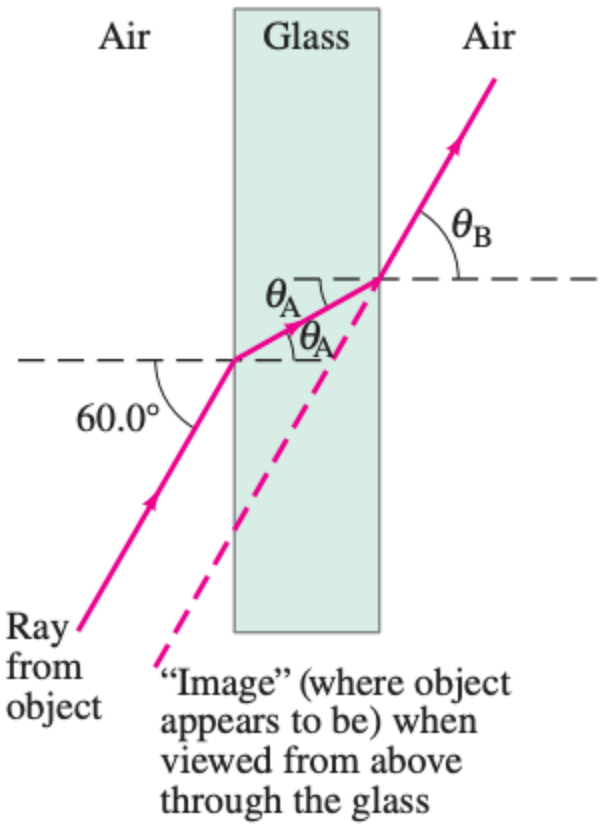
In a laboratory, a rectangular loop of wire surrounds the origin in the xz-plane, with extent H in the z-direction and extent L in the x-direction (figure). The loop carries current I in the counterclockwise direction as viewed from the positive y-axis. A magnetic field $\vec{B} = B\hat{k}$ is present. The electromagnetic field is $\vec{E} \perp \vec{B} = (0, \vec{B})$ in an inertial frame S, and then in another frame S' moving at velocity $\vec{v}$ relative to S. What is the component of the magnetic field $\vec{B}'$, perpendicular to $\vec{v}$?

$B' = \gamma(B - (v \times E)/c^2)$

where γ is the Lorentz factor and E is electric field.

Since $E \perp B$, the component of B' perpendicular to v remains B

Question 16:



Light traveling in air strikes a flat piece of uniformly thick glass at an incident angle of 60.0°, as shown in figure.The index of refraction of the glass is 1.50. What is the angle $heta_B$ at which the ray emerges from the glass?

$n_1 \sin\theta_1 = n_2 \sin\theta_2$.

$1 \times \sin 60^{\circ} = 1.5 \sin\theta_2$.

$\therefore \theta_2 = 35.3^{\circ}$.

For the second interface

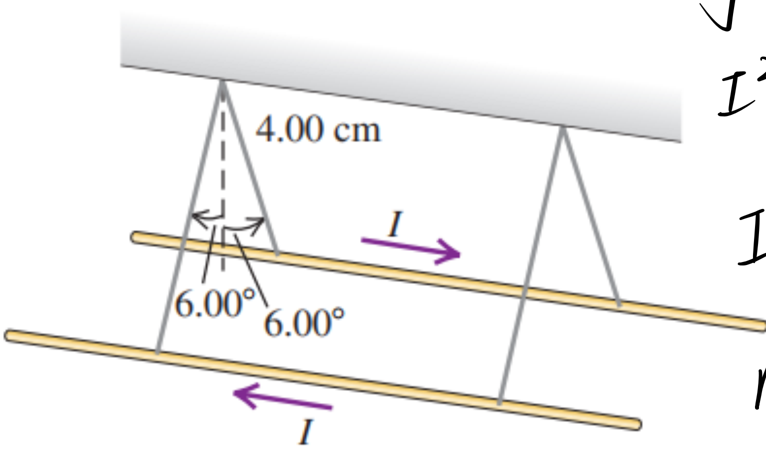
$1.5 \times \sin 35.3^{\circ} = 1 \times \sin\theta_B$.

$\sin\theta_B = 1.5 \times \sin 35.3^{\circ} = 0.866$.

$\theta_B = 60^{\circ}$

For each wire:

Question 17:



$mg\tan 6° = \mu_0 I^2 / 2\pi r$.

$I^2 = \dfrac{2\pi r \times mg \times \tan 6°}{\mu_0}$

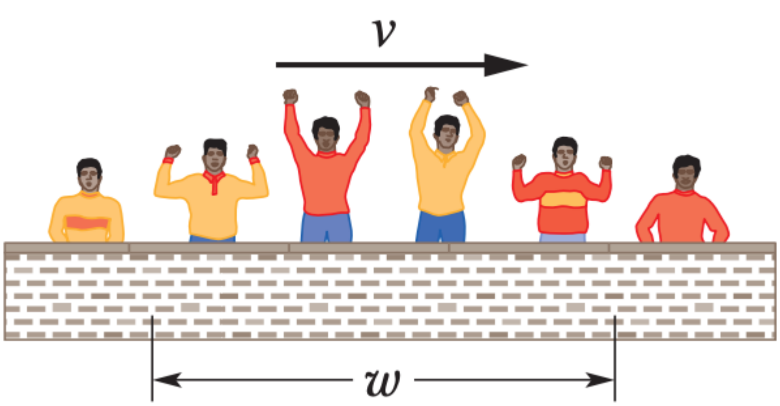
$I = \sqrt{\dfrac{2\pi r \times mg \times \tan 6°}{\mu_0}}$.

$r = 2\times 0.04 \times \sin 6° = 0.0084m$.

Two long, parallel wires hang by $4.00\,\mathrm{cm}$-long cords from a common axis. The wires have a mass per unit length of $0.0125\,\mathrm{kg/m}$ and carry the same current in opposite directions. What is the current in each wire if the cords hang at an angle of 6.00° with the vertical?

$\therefore I = 0.66A$

Question 18:



During sporting events within large, densely packed stadiums, spectators will send a wave (or pulse) around the stadium. As the wave reaches a group of spectators, they stand with a cheer and then sit. At any instant, the width w of the wave is the distance from the leading edge (people are just about to stand) to the trailing edge (people have just sat down). Suppose a human wave travels a distance of 853 seats around a stadium in 39 s, with spectators requiring about 1.8 s to respond to the wave's passage by standing and then sitting. What is the width w (in number of seats)?

Speed of the wave $= \dfrac{853 \text{ seats}}{39 s} = 21.87$ seats/s.

Time for one person to respond $= 1.8 s$.

width $=$ Speed $\times$ Time $= 21.87 \times 1.8 = 39.4$ seats $= 39$ seats.